



Validation of a CFD model with a triple-lidar system upstream of a wind turbine in complex terrain

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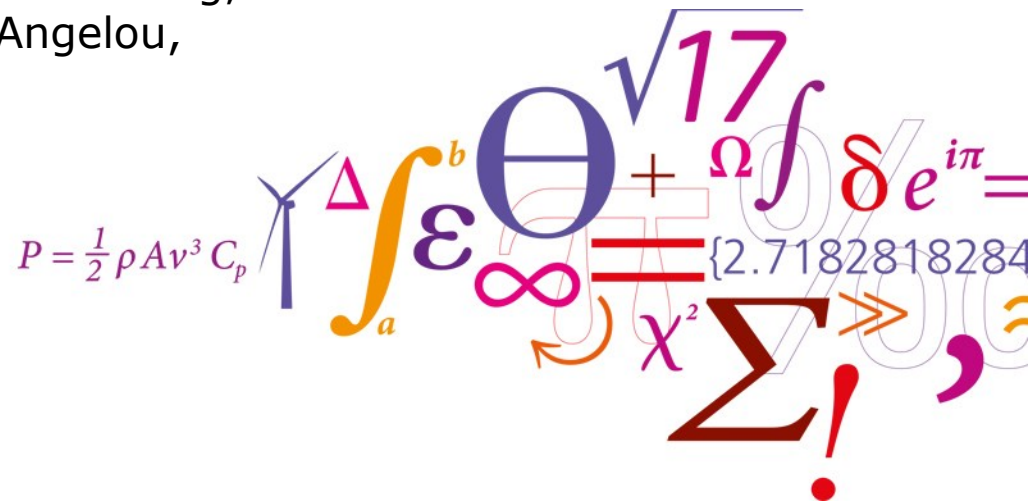
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Validation of a CFD model with a triple-lidar system upstream of a wind turbine in complex terrain

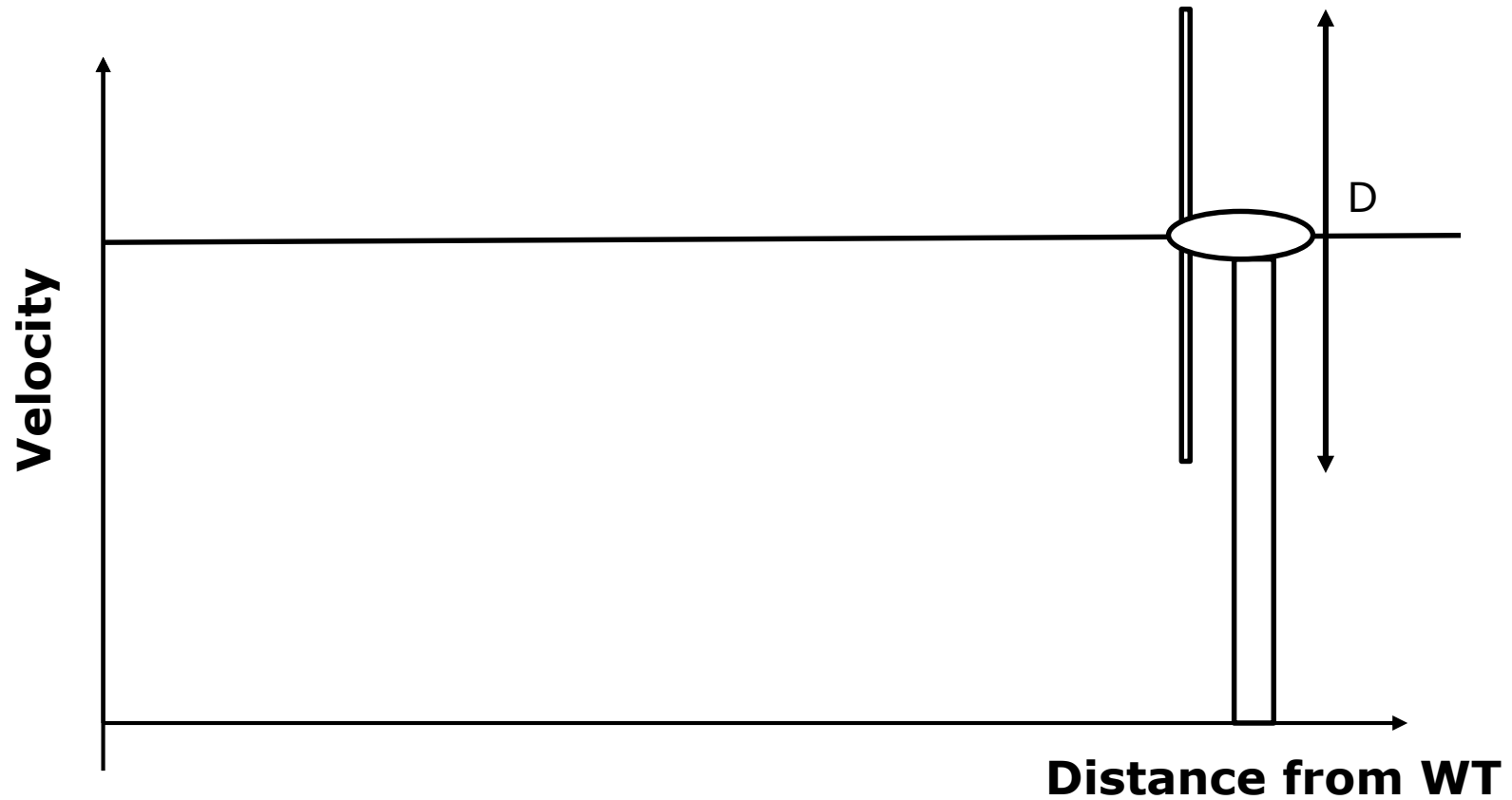
Alexander Meyer Forsting, Niels Troldborg,
Andreas Bechmann, Nikolas Angelou,
Nikola Vasiljevic



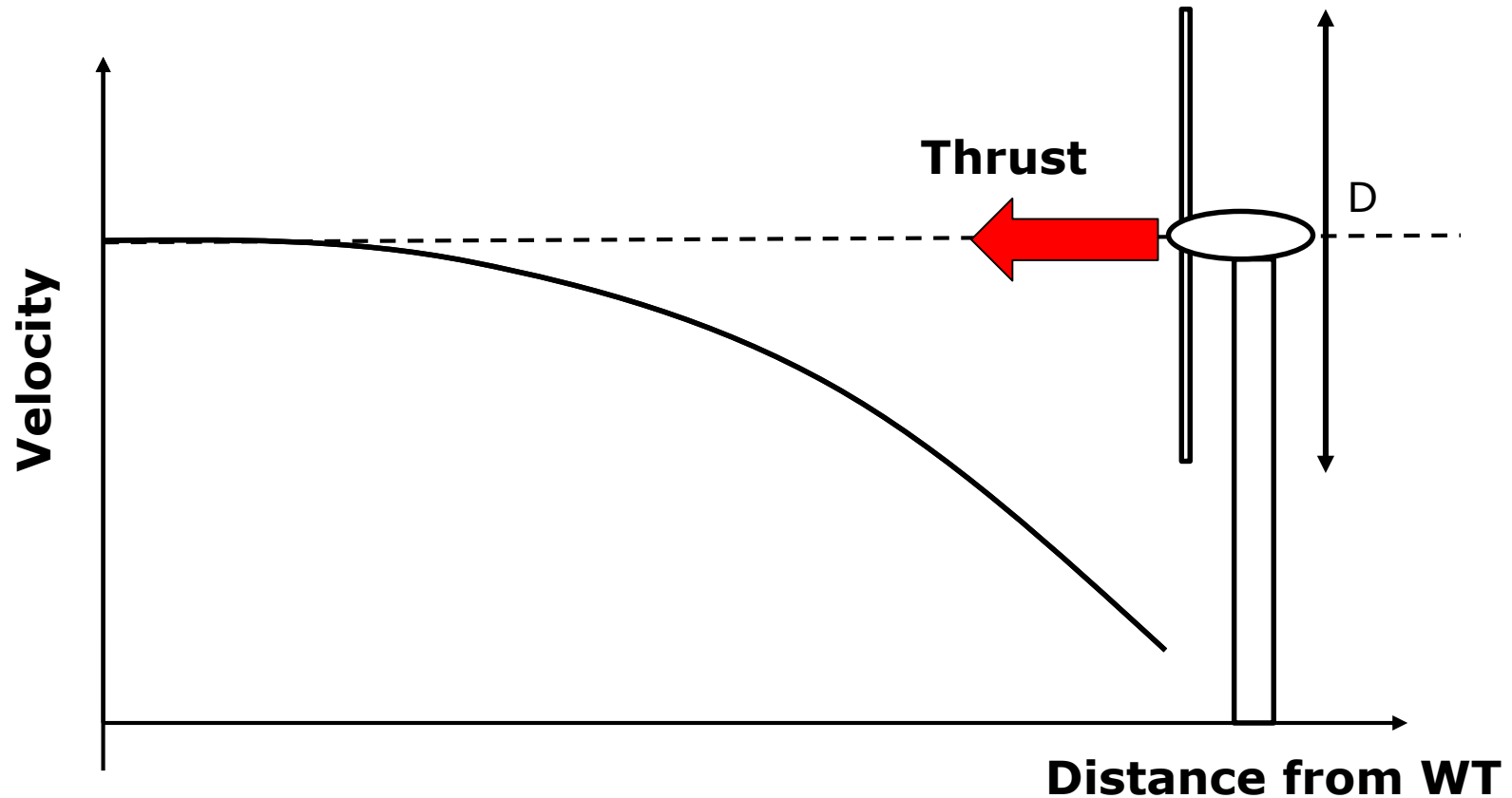
Overview

- The induction zone
- Power curve measurements
- Computational method
- CFD simulations
- Triple-lidar measurements in the induction zone
- CFD – measurement comparison
- Conclusion
- Future work

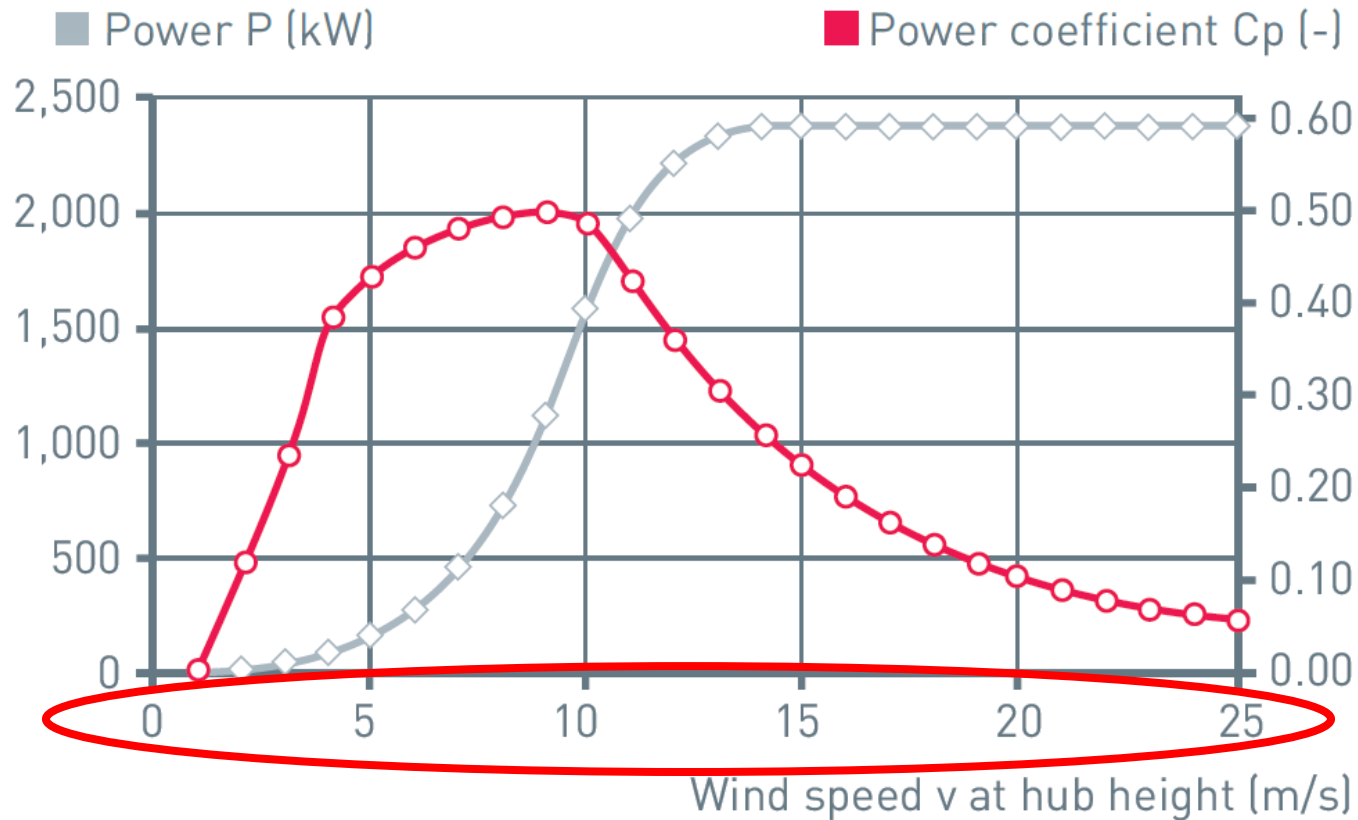
The induction zone



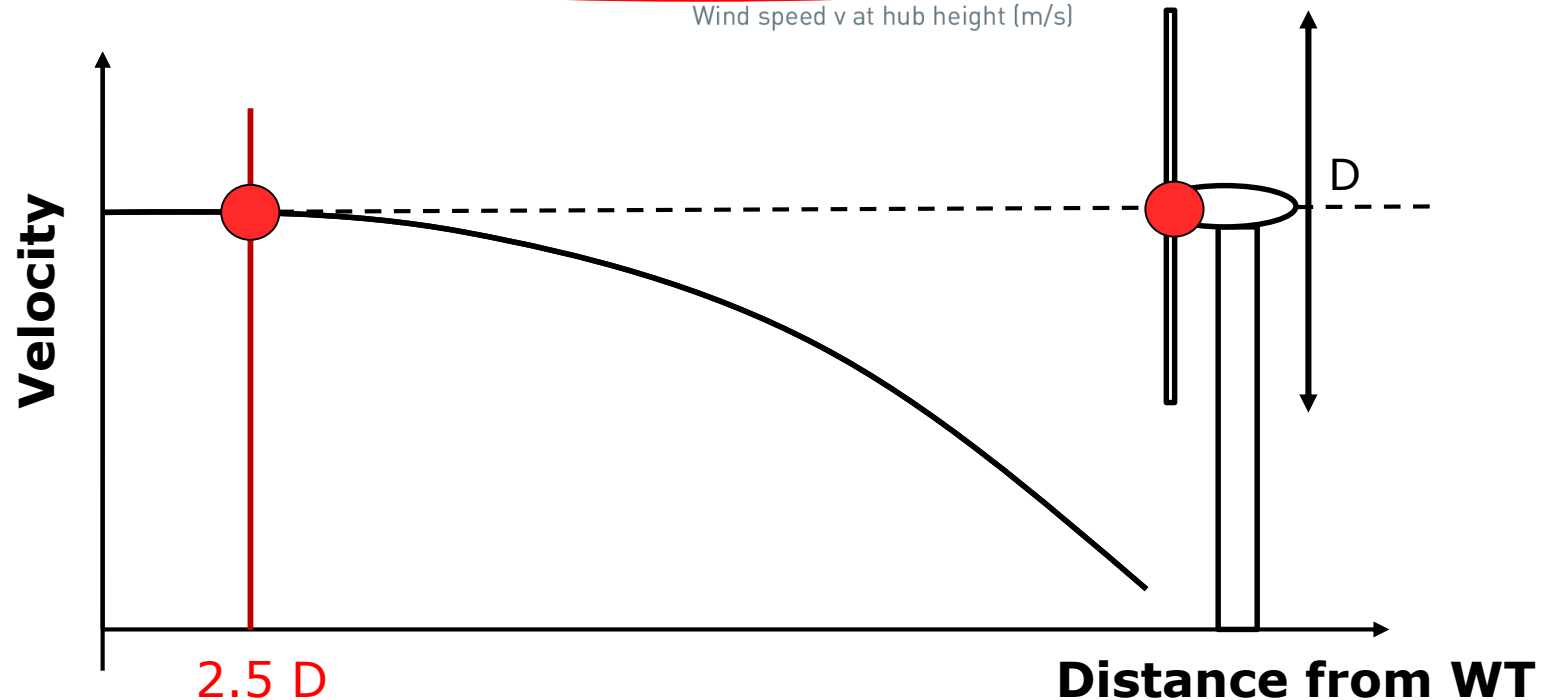
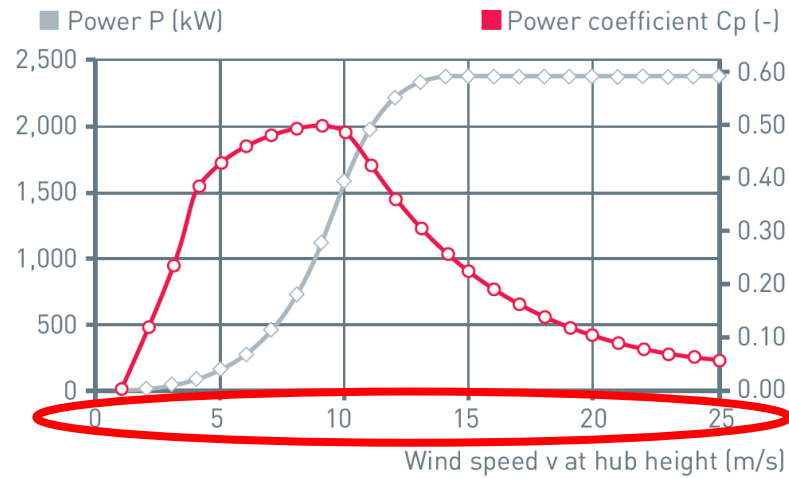
The induction zone



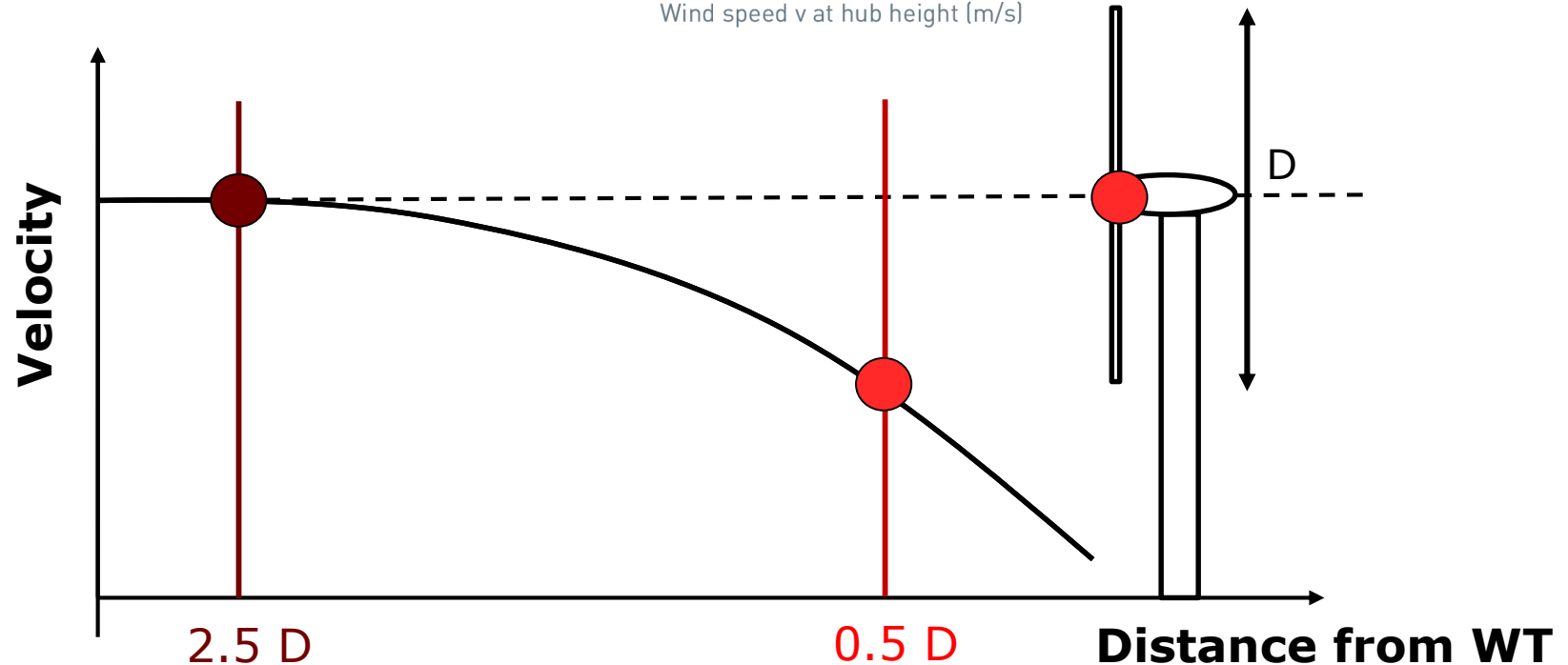
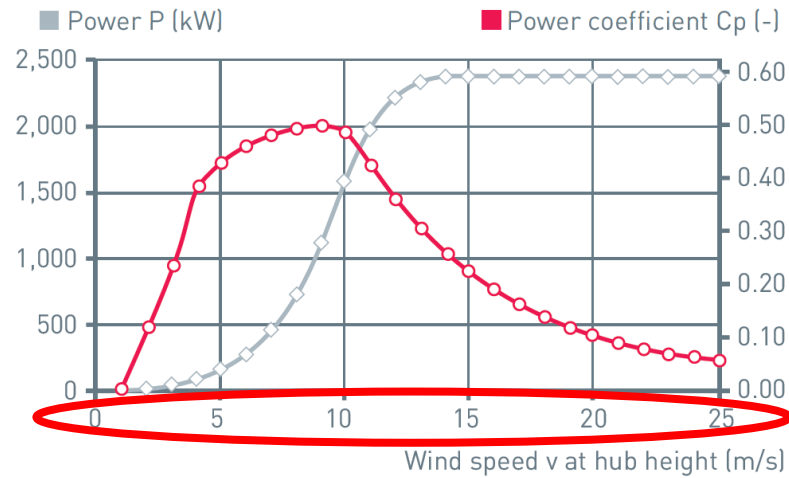
Power curve measurements



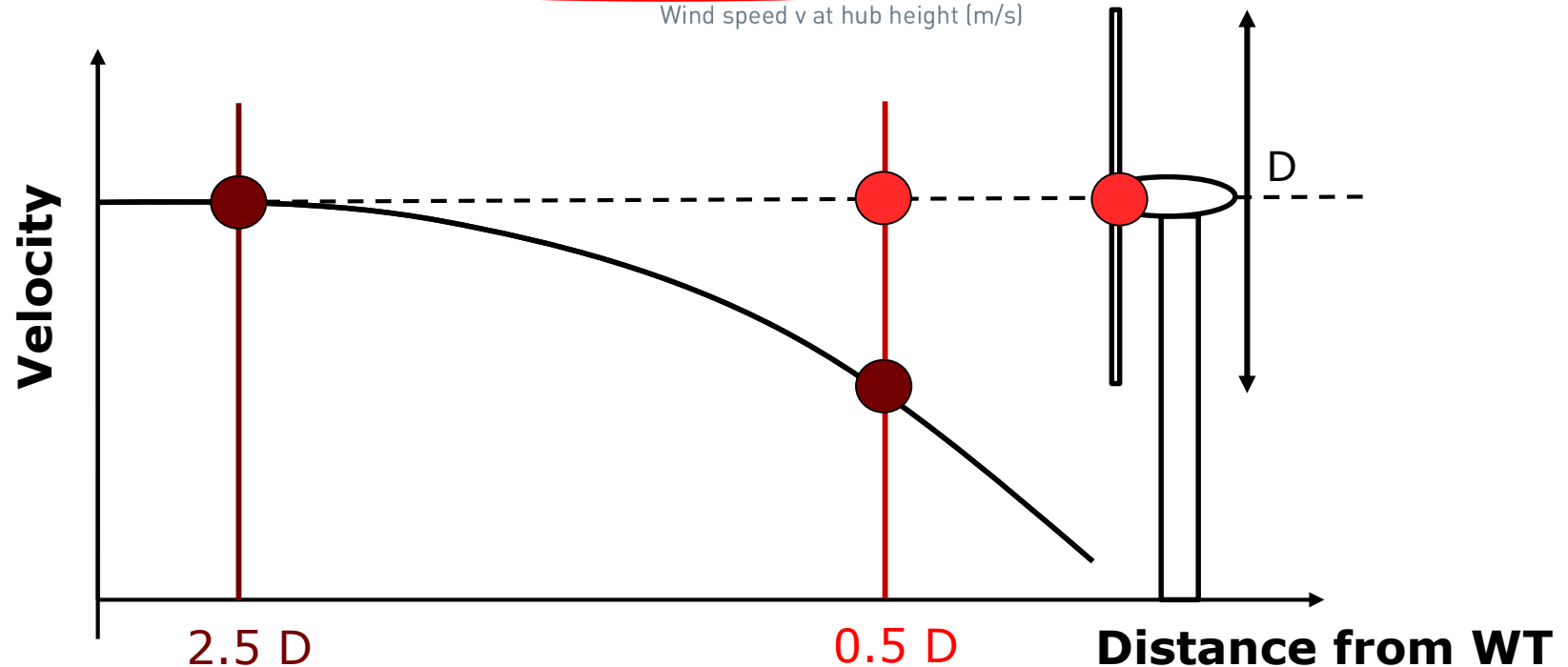
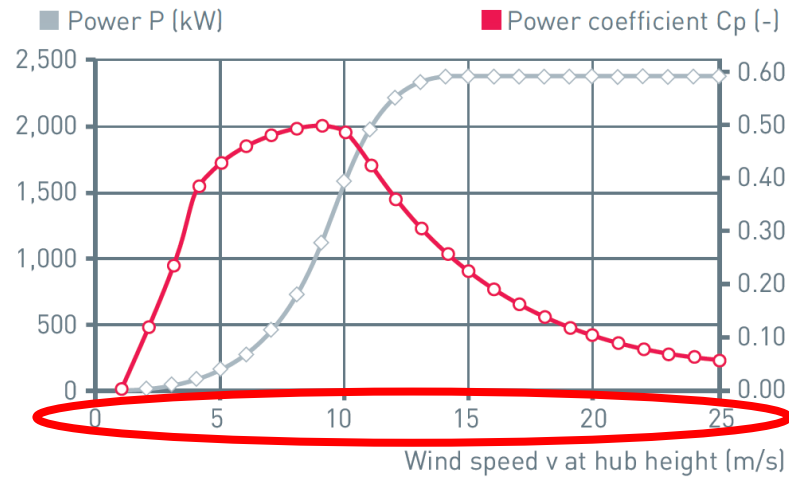
Power curve measurements



Power curve measurements



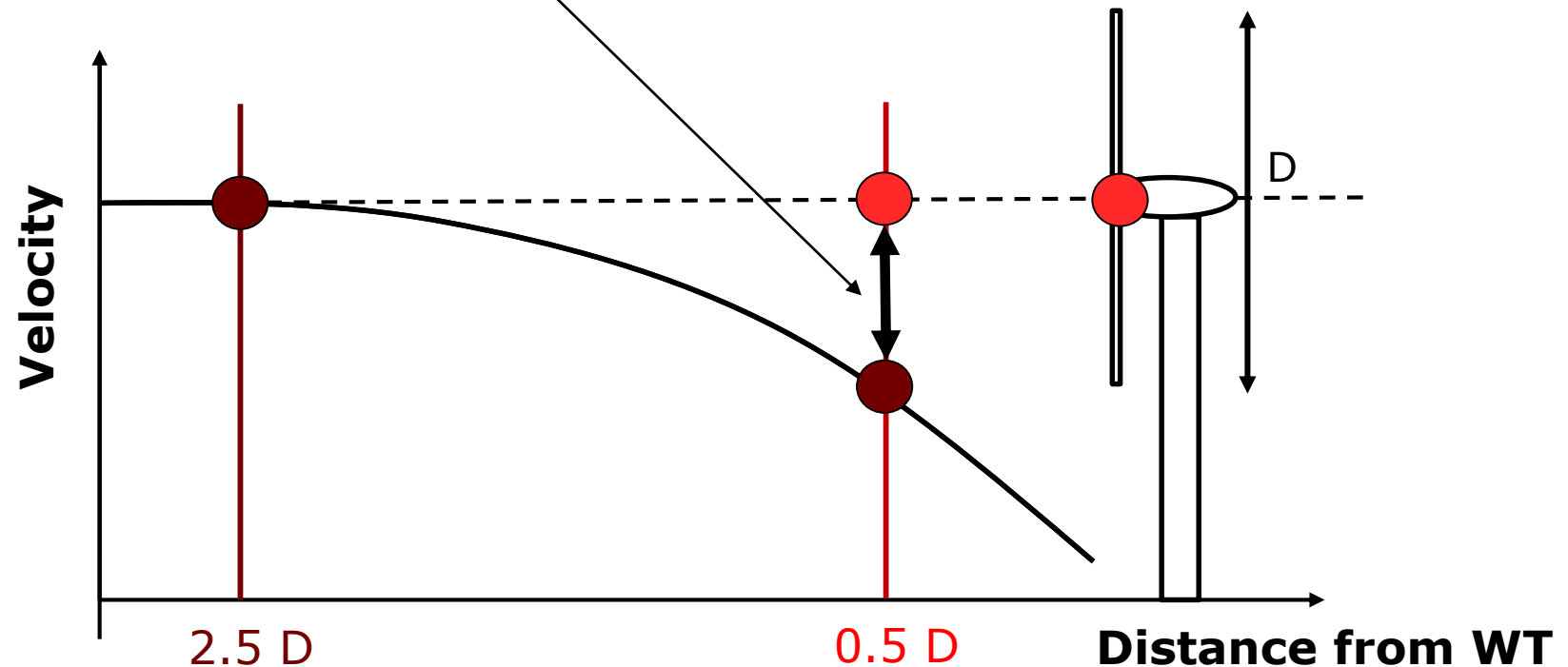
Power curve measurements



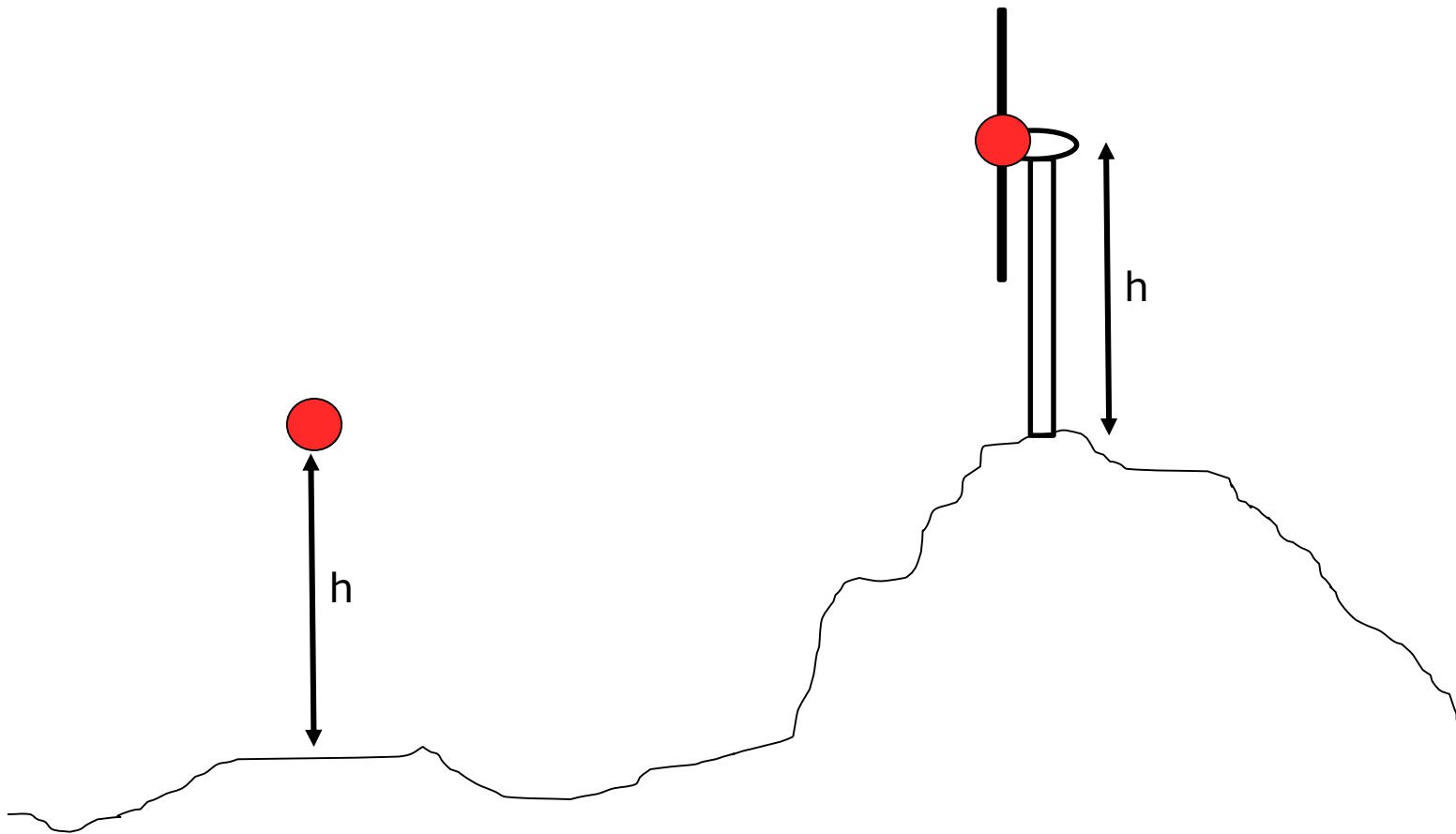
Power curve measurements

Induction zone model

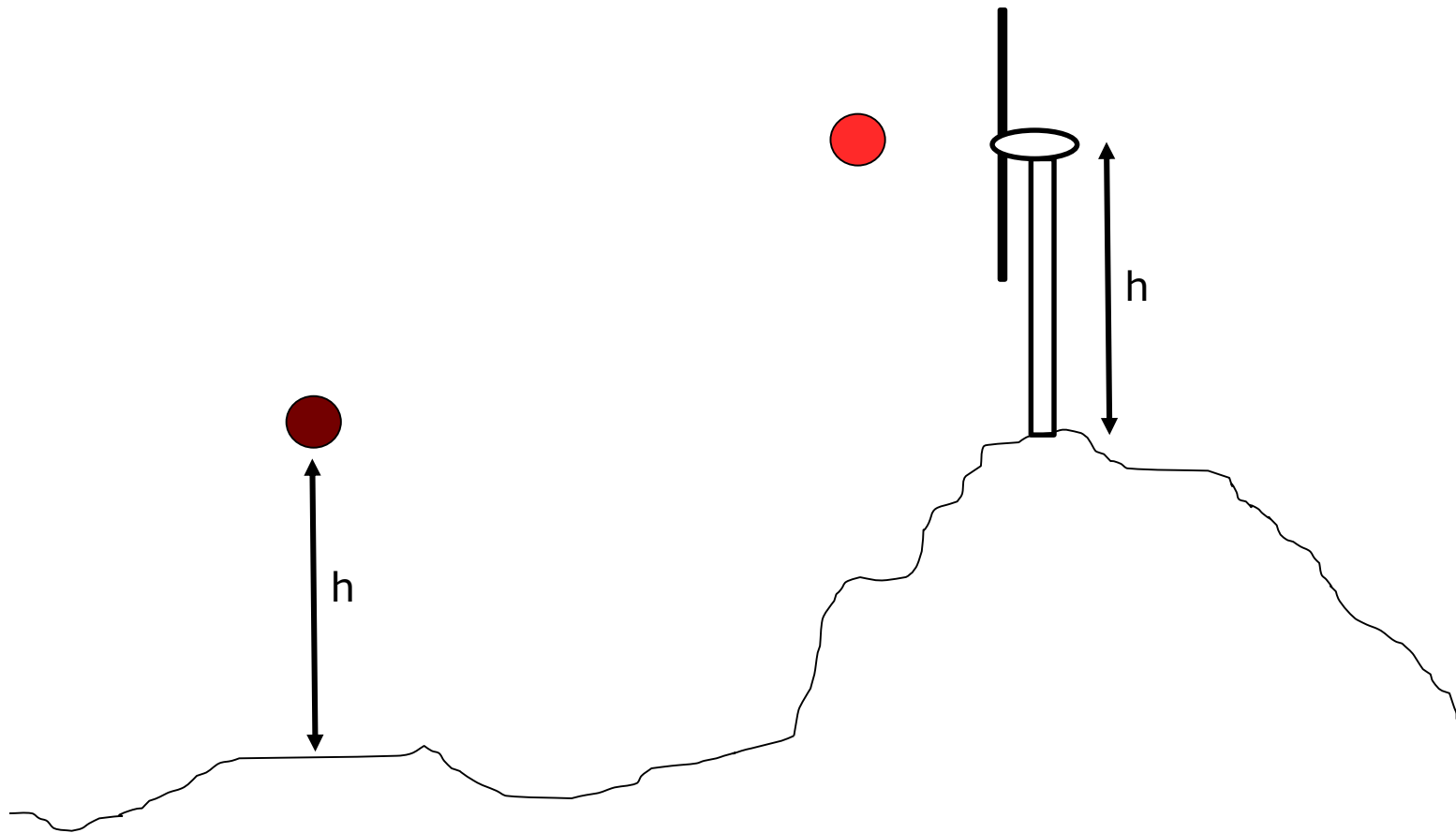
- Predict uncertainty
- Capture thrust dependency



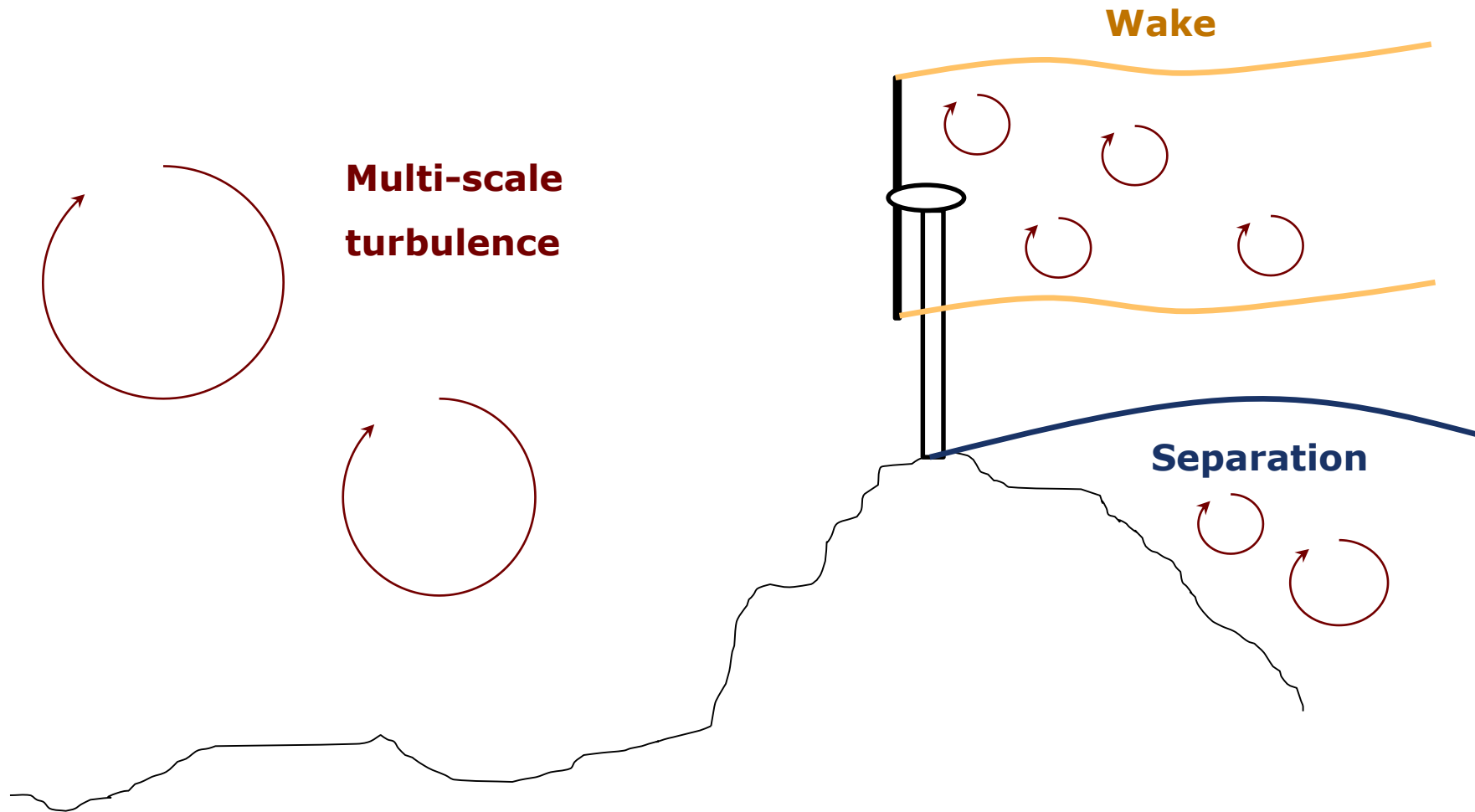
Power curve measurements in complex terrain



Power curve measurements in complex terrain



Modeling the induction zone in complex terrain



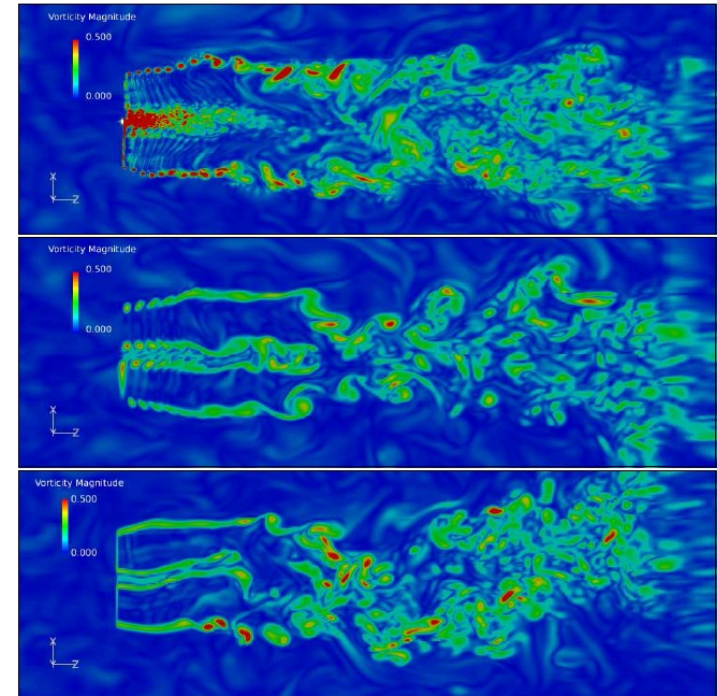
EllipSys3D

General

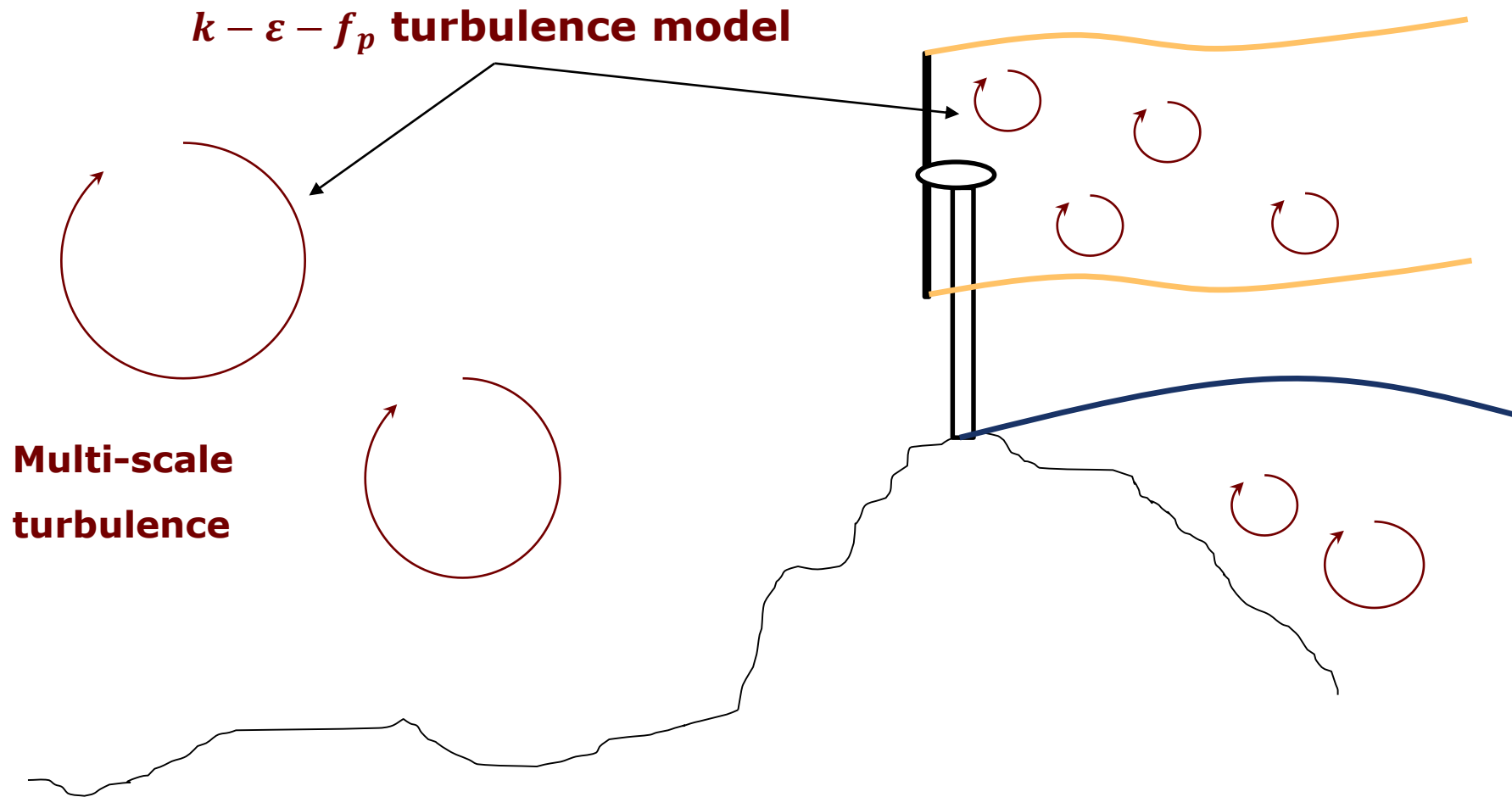
- Multi-purpose finite volume solver
- Block-structured grid with collocated variables
- Highly parallelised
- Body forces are implemented via modified Rhie-Chow algorithm

Complex terrain

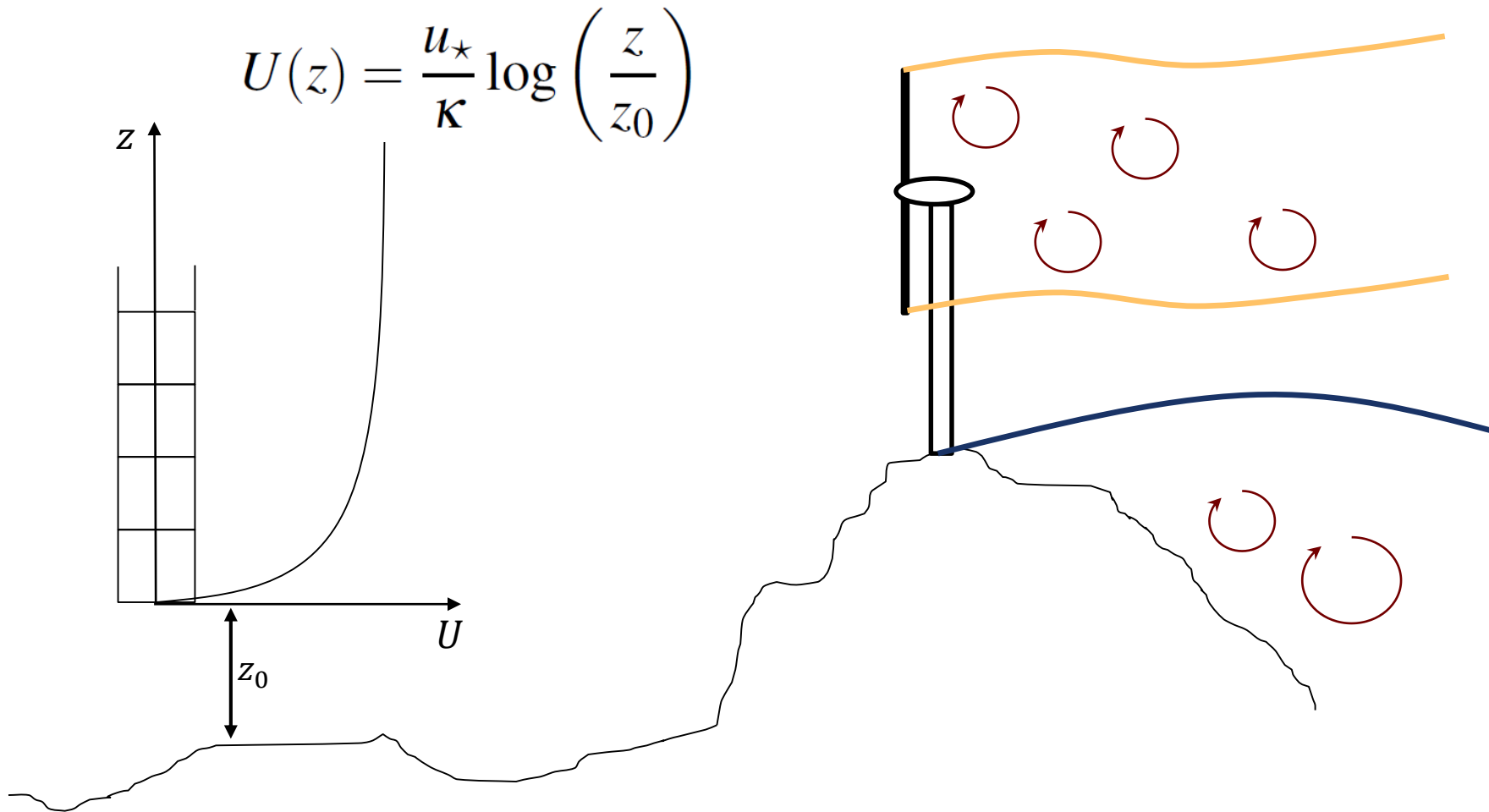
- Steady-state incompressible RANS
- QUICK scheme solved convective terms
- SIMPLE the pressure-linked terms



Modeling the induction zone in complex terrain



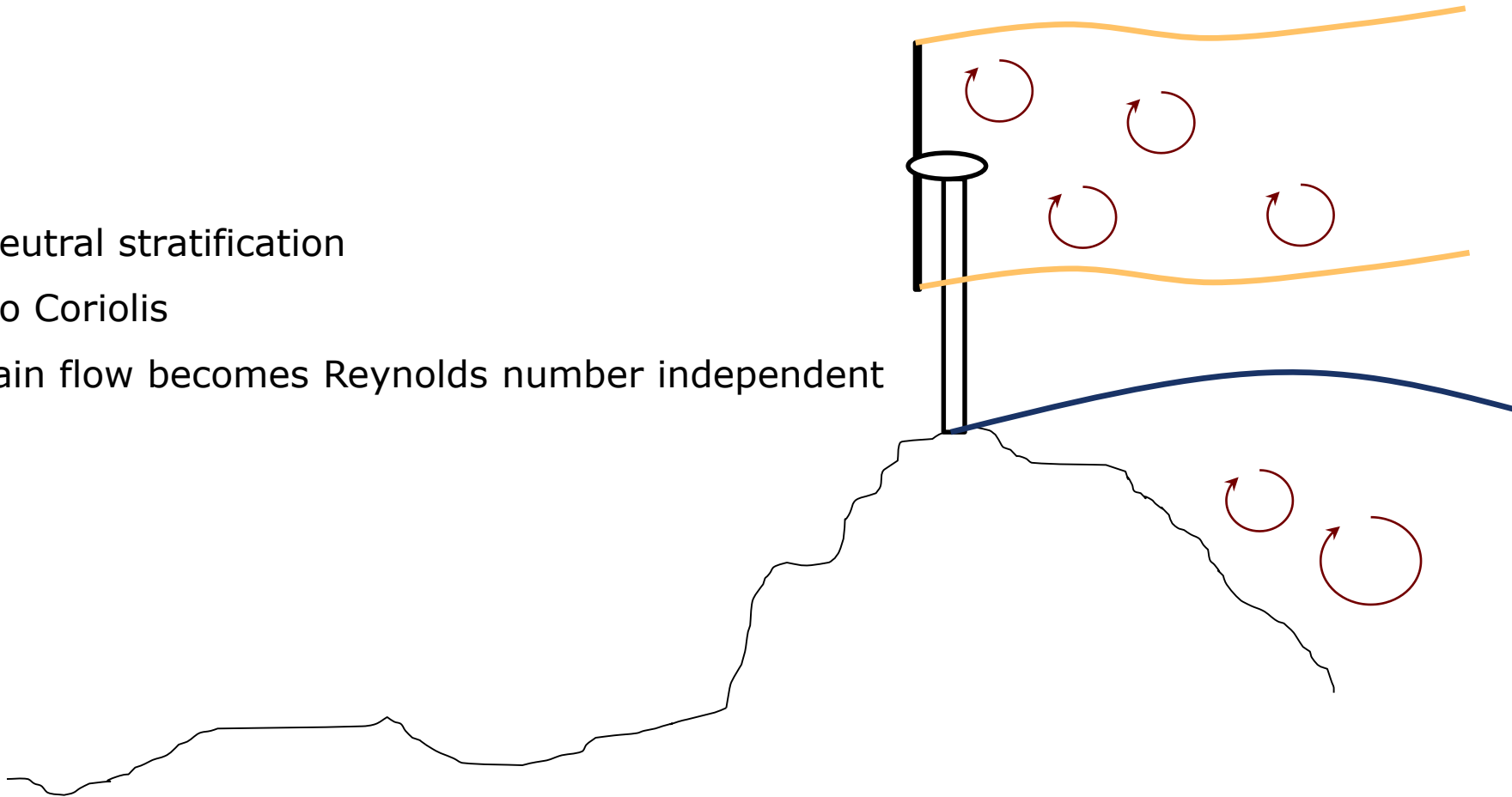
Modeling the induction zone in complex terrain



Modeling the induction zone in complex terrain

- Neutral stratification
- No Coriolis

Terrain flow becomes Reynolds number independent



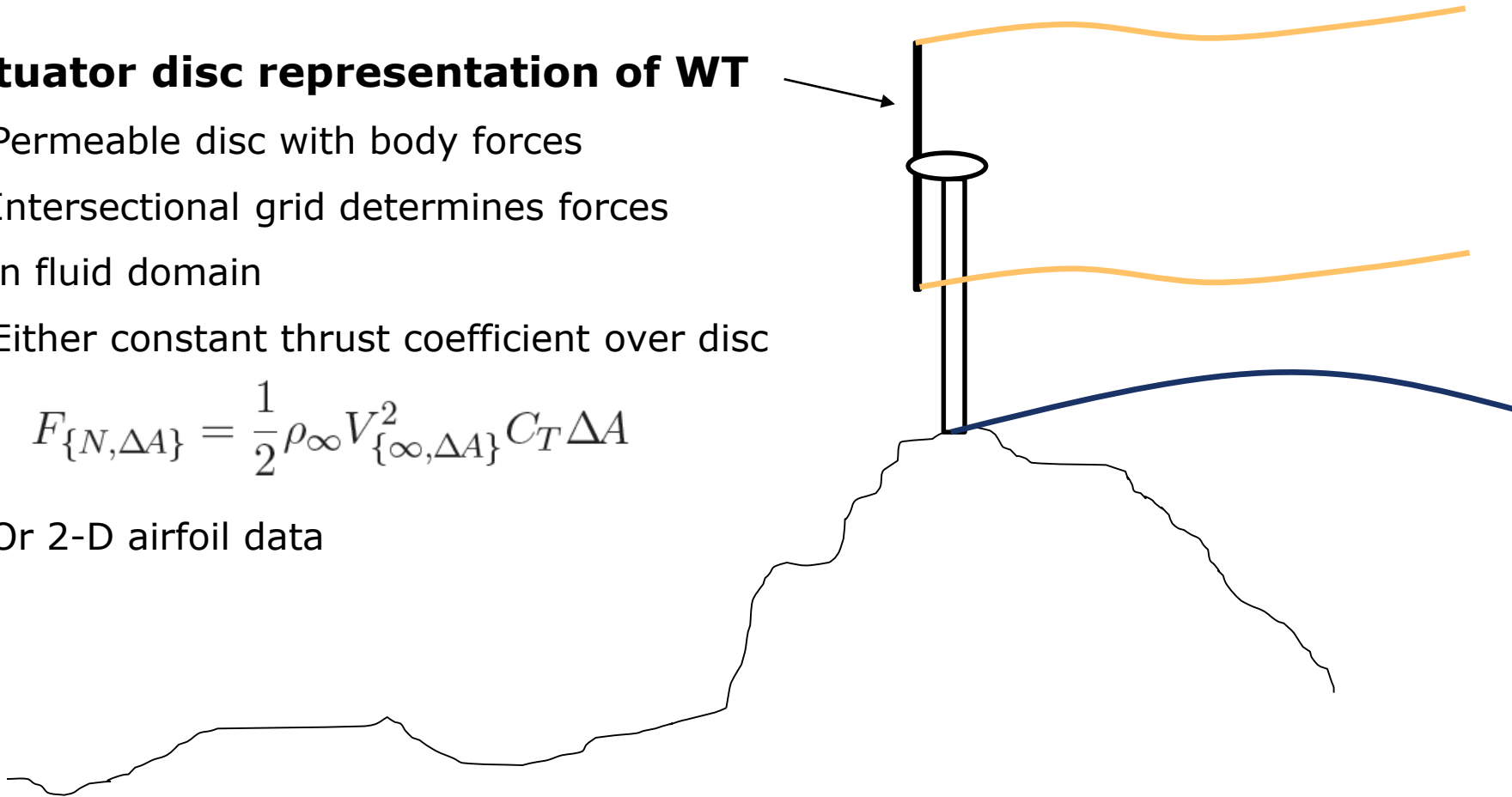
Modeling the induction zone in complex terrain

Actuator disc representation of WT

- Permeable disc with body forces
- Intersectional grid determines forces in fluid domain
- Either constant thrust coefficient over disc

$$F_{\{N, \Delta A\}} = \frac{1}{2} \rho_{\infty} V_{\{\infty, \Delta A\}}^2 C_T \Delta A$$

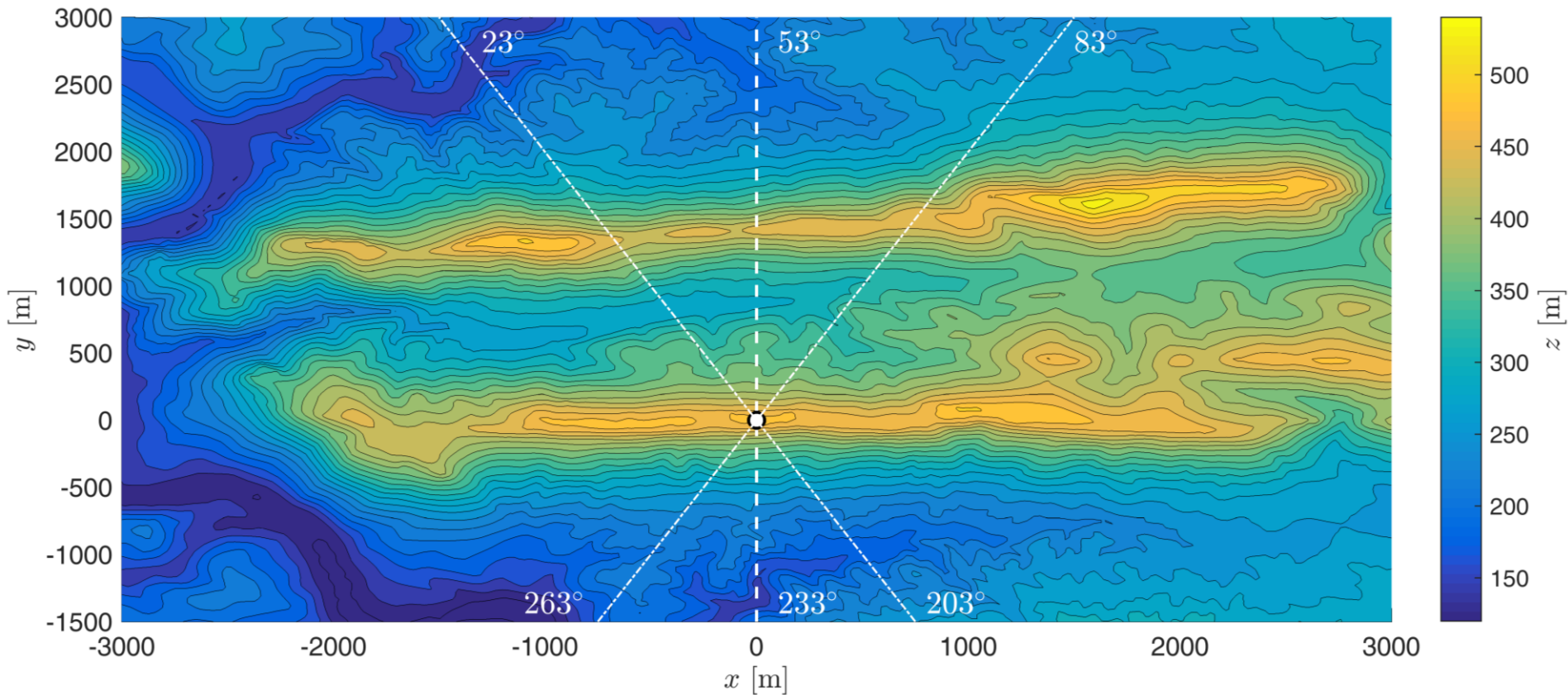
- Or 2-D airfoil data



Complex terrain test case: Perdigão



Complex terrain test case: Perdigão



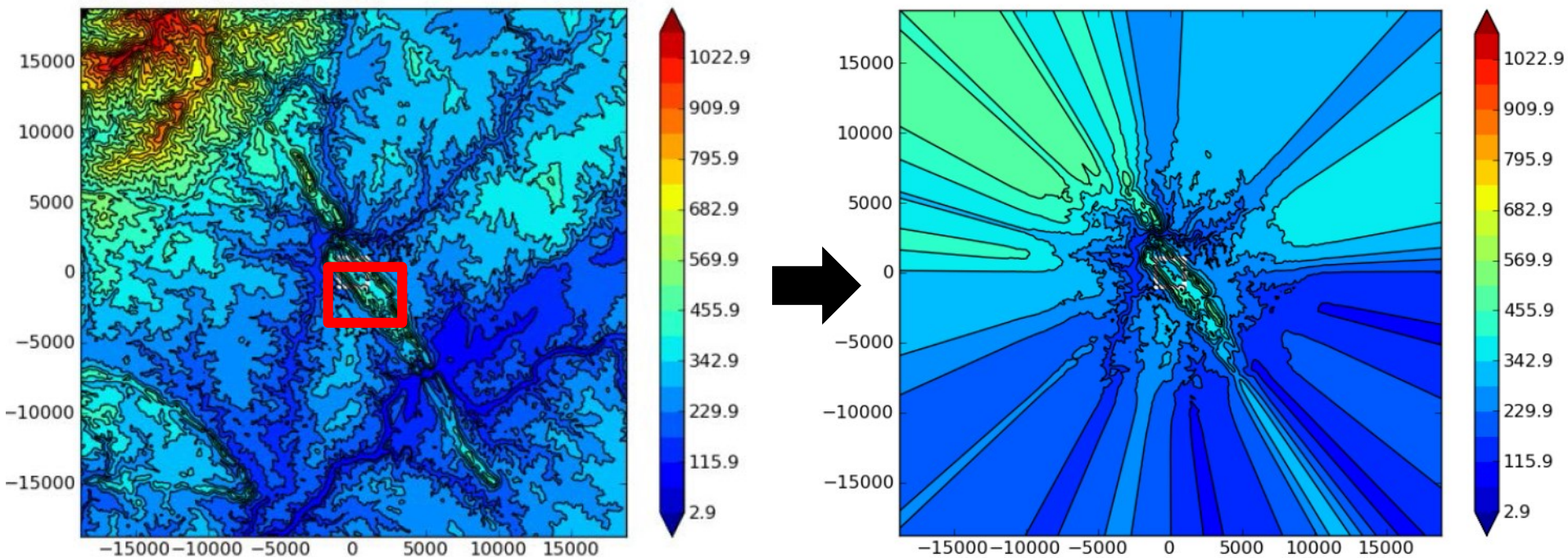
Complex terrain test case: Perdigão



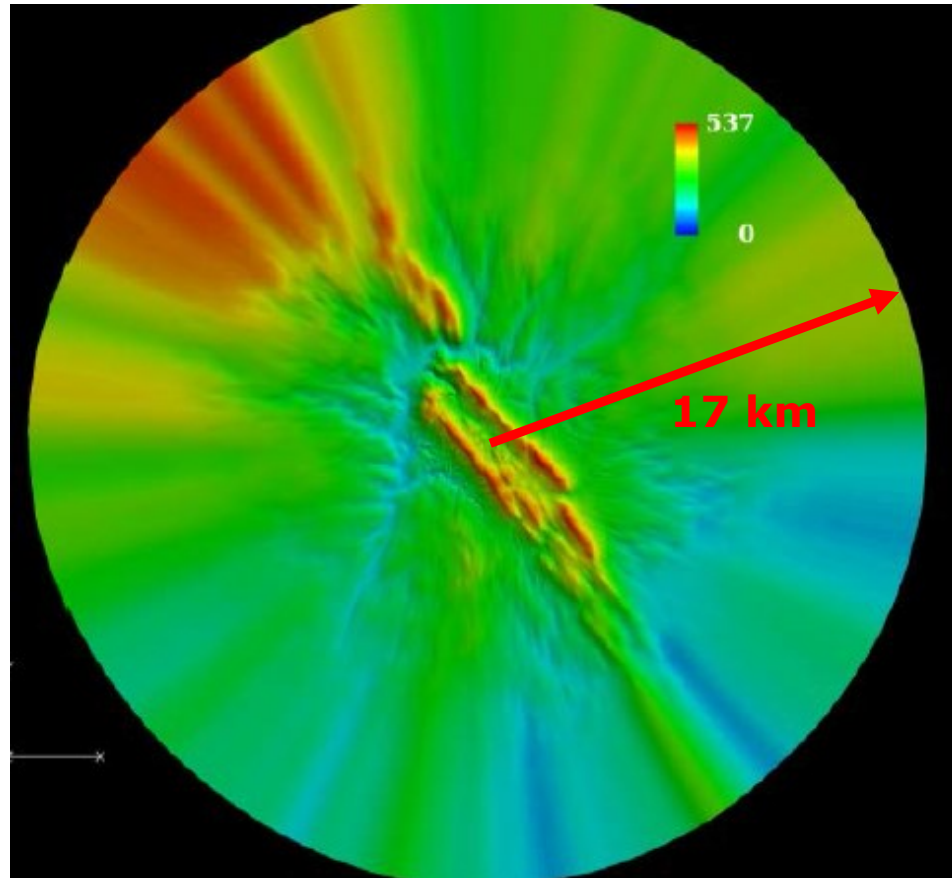
Terrain treatment for mesh generation

Far-field terrain and reference roughness

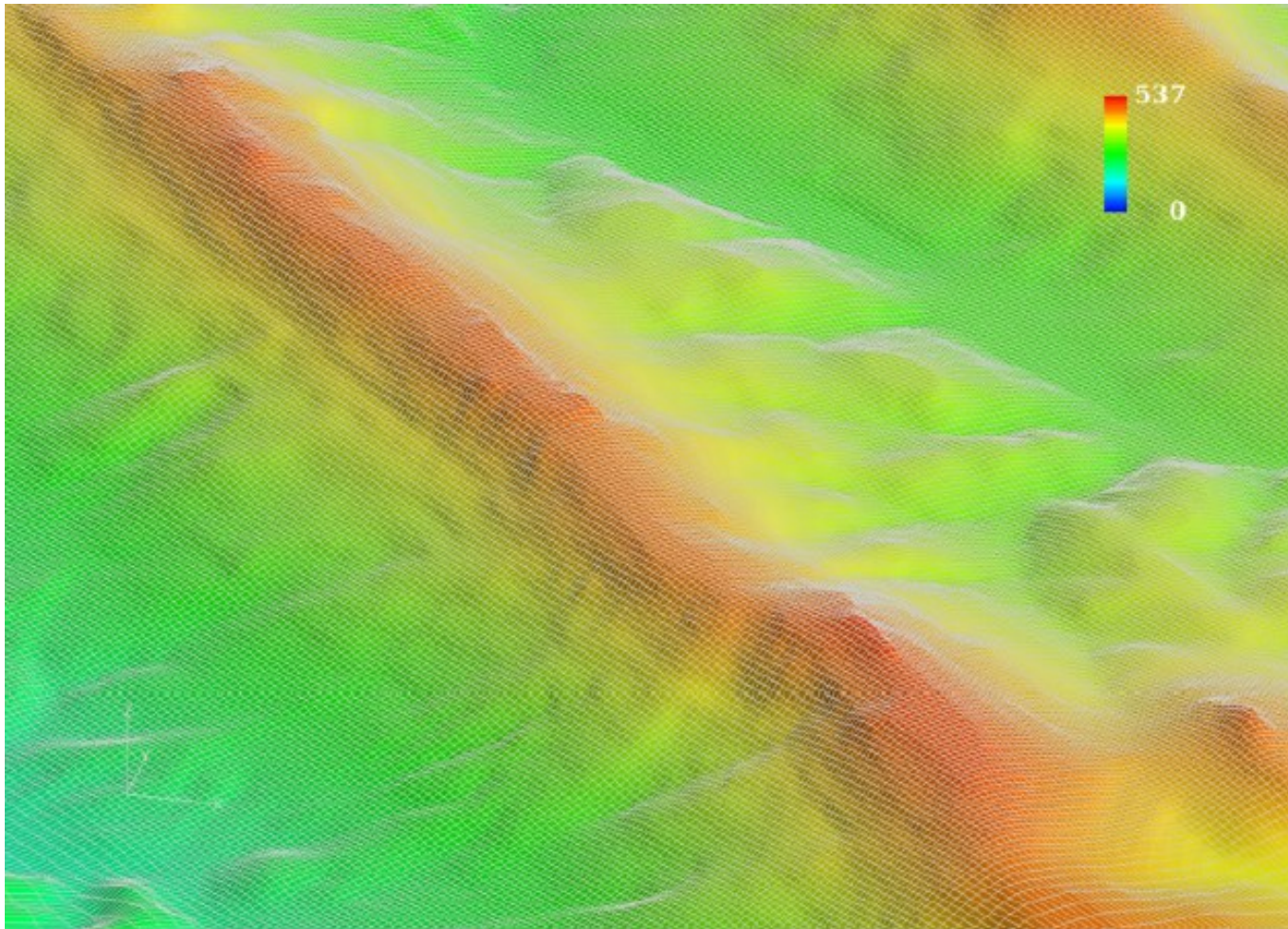
- Smoothed over grid spacing and towards the edges of the domain



The domain

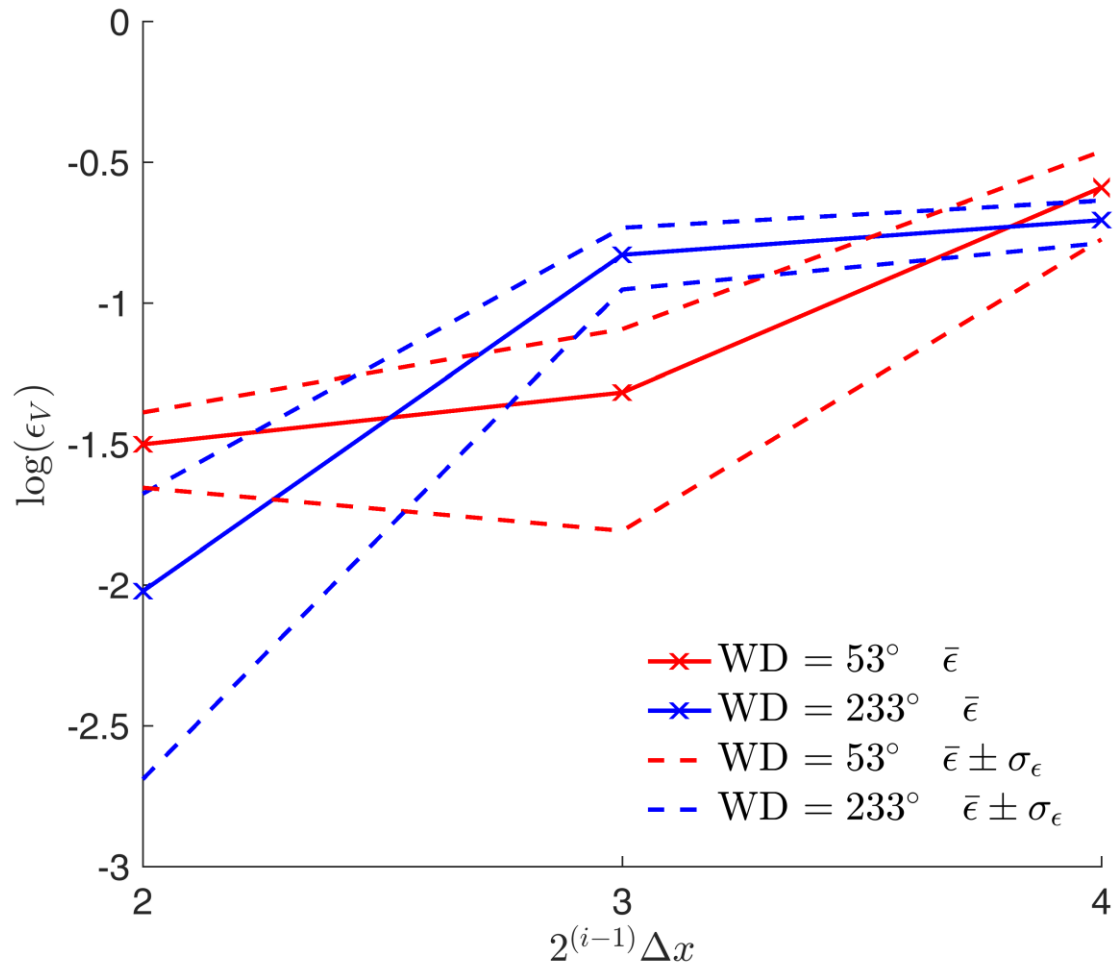


The domain



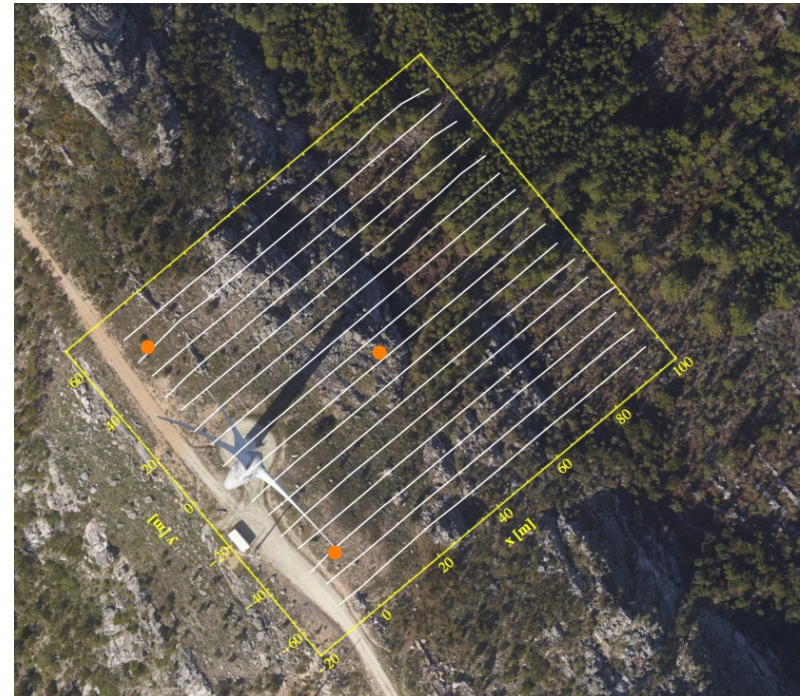
Grid sensitivity

$$\Delta x = \frac{R}{16} = 2.56 \text{ m} \longrightarrow 2.13 \text{ M cells}$$



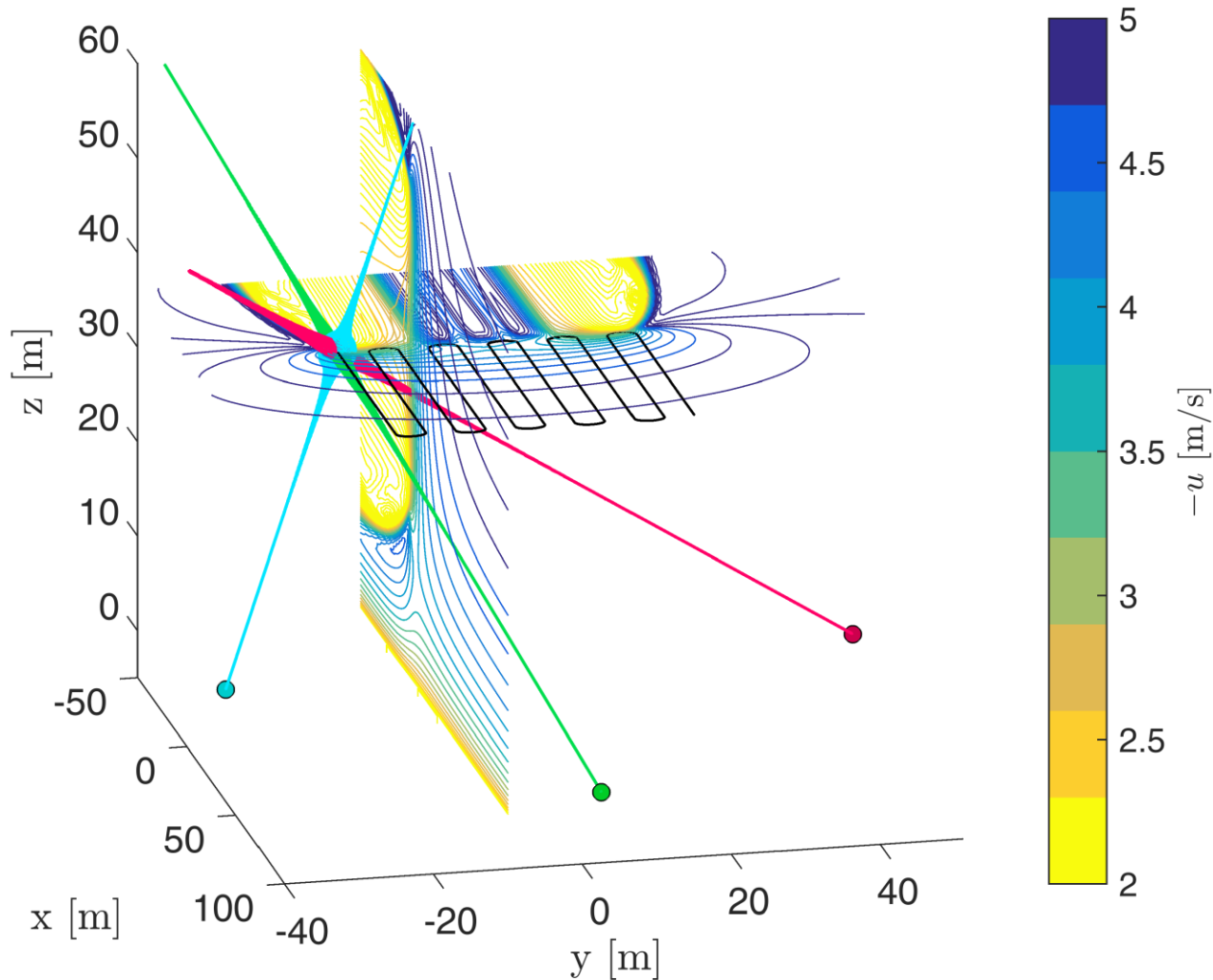
Measurements at Perdigão

- Synchronised lidar measurements around WT and valley



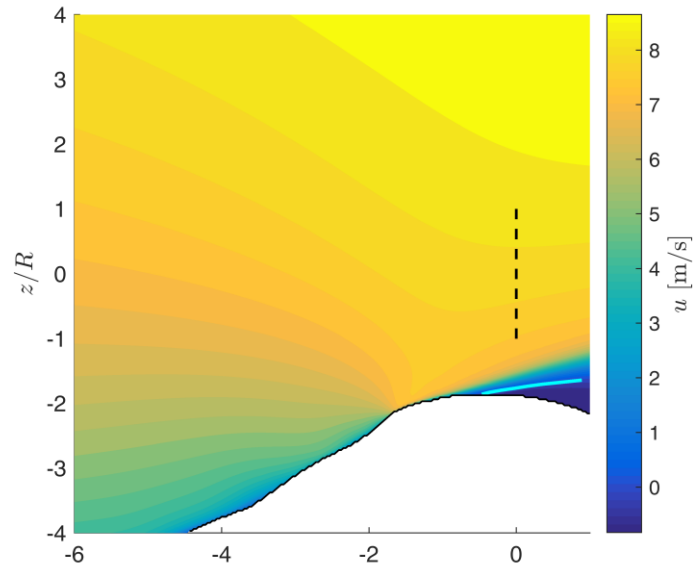
Measurements at Perdigão

Synchronised triple-lidar

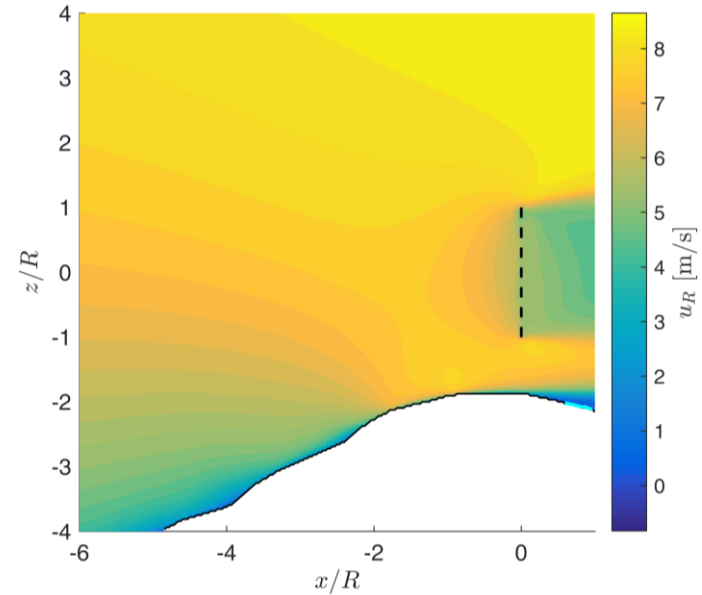
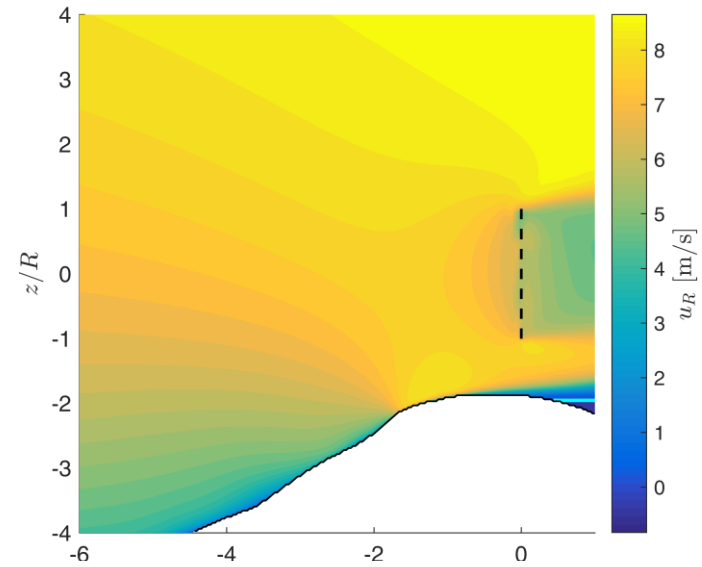
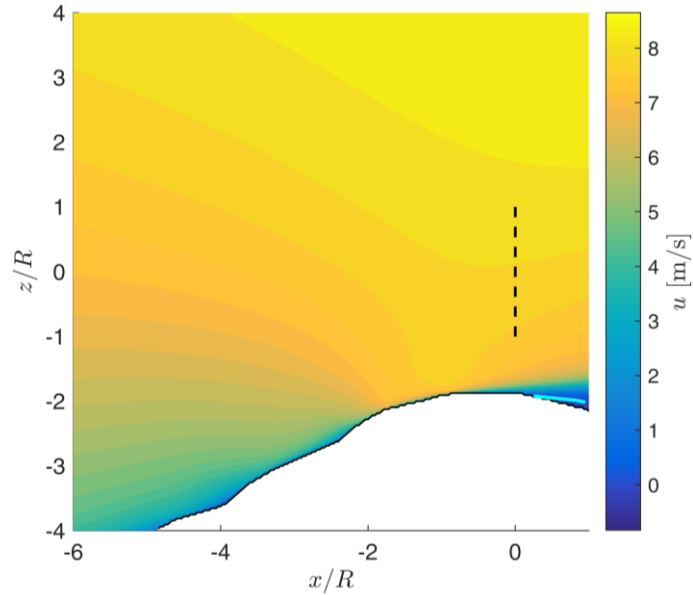


CFD Results

218°



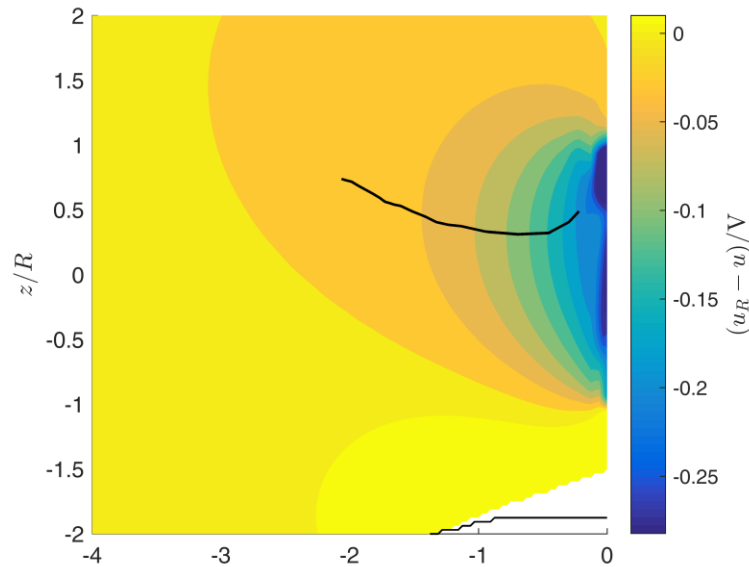
263°



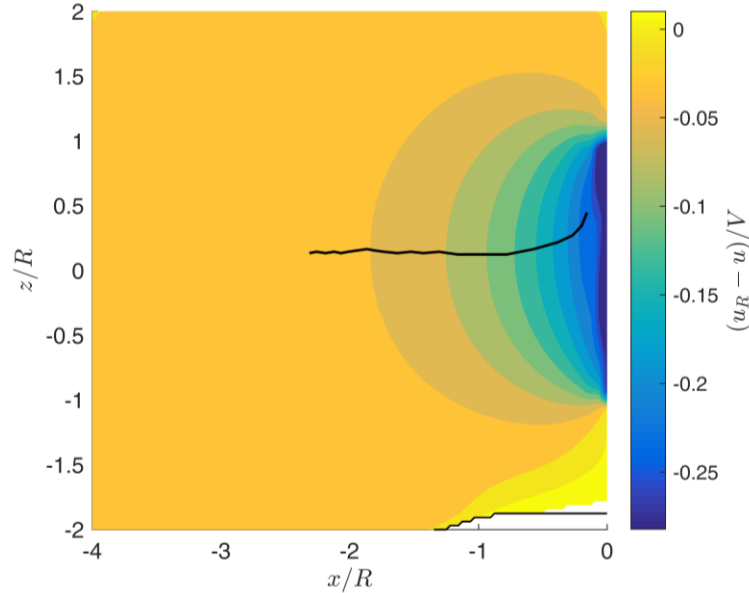
CFD Results

Wind directions

218°

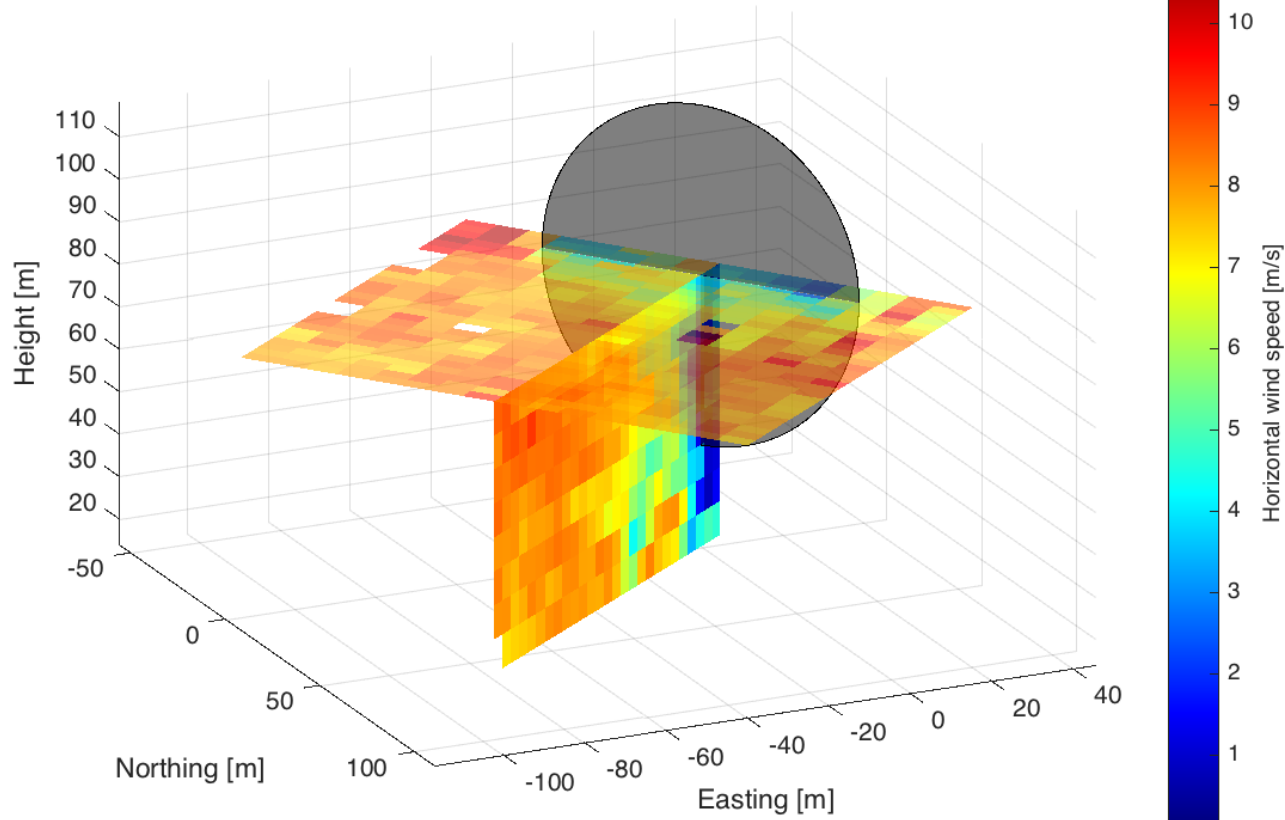


263°



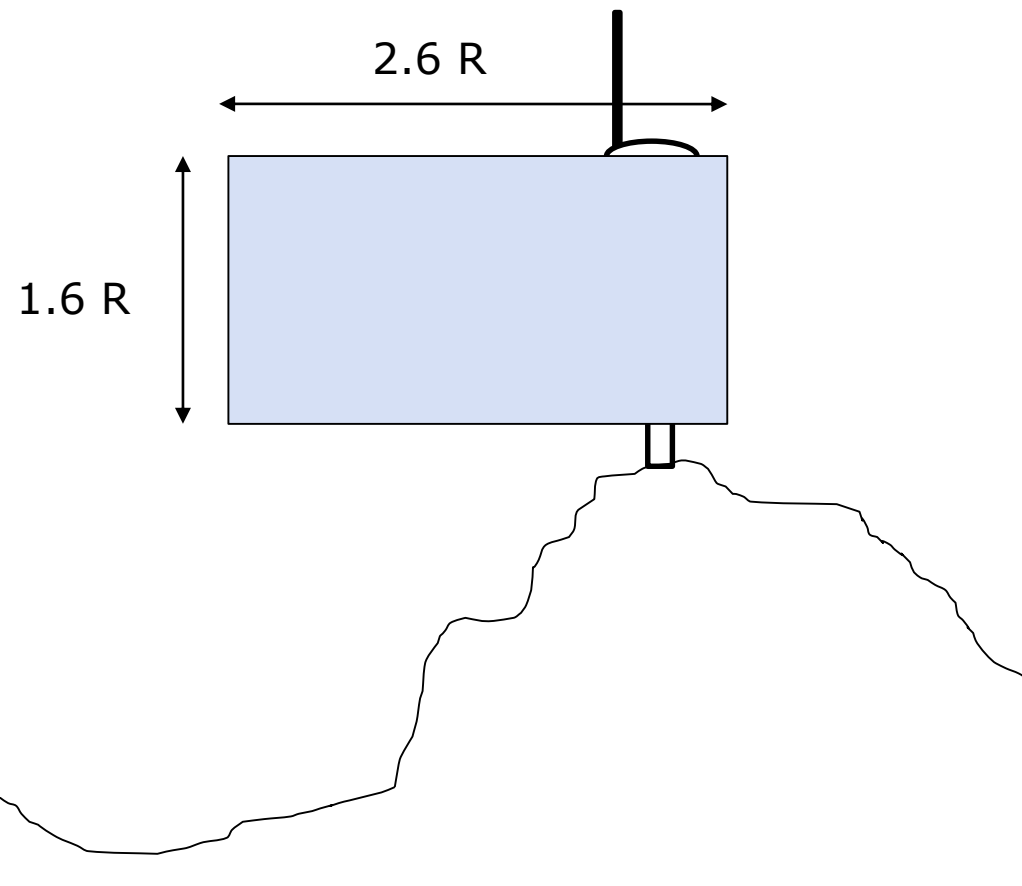
Triple-lidar results

Start: 2015/05/15 17:50 $\overline{v_H}$: 7.15m/s $\overline{v_{rotor}}$: 6.85m/s \overline{P} : 542kW
 End: 2015/05/15 18:00 \overline{DIR} : 26.62° $\overline{DIR_{NA}}$: 34° Online

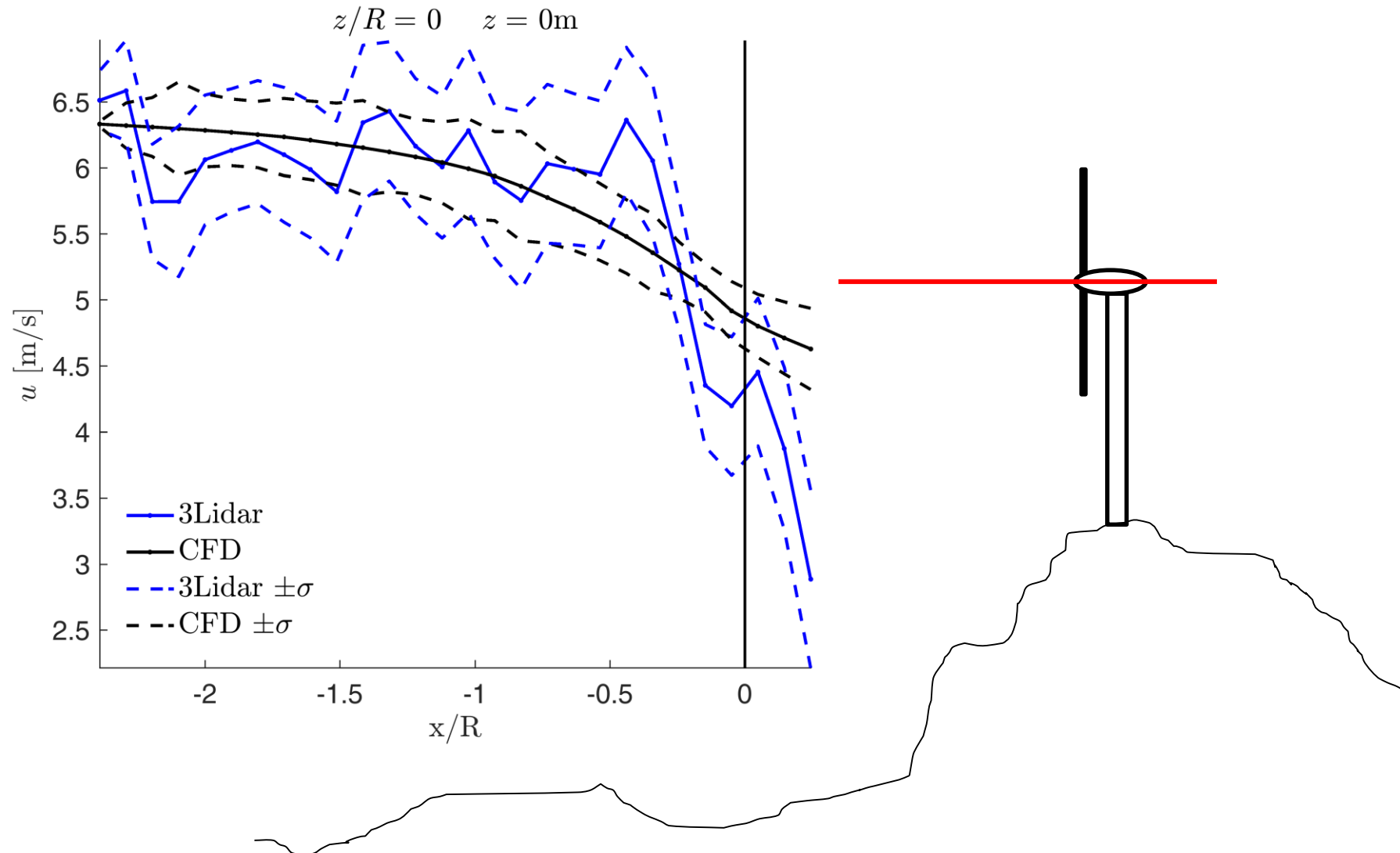


By R. Menke

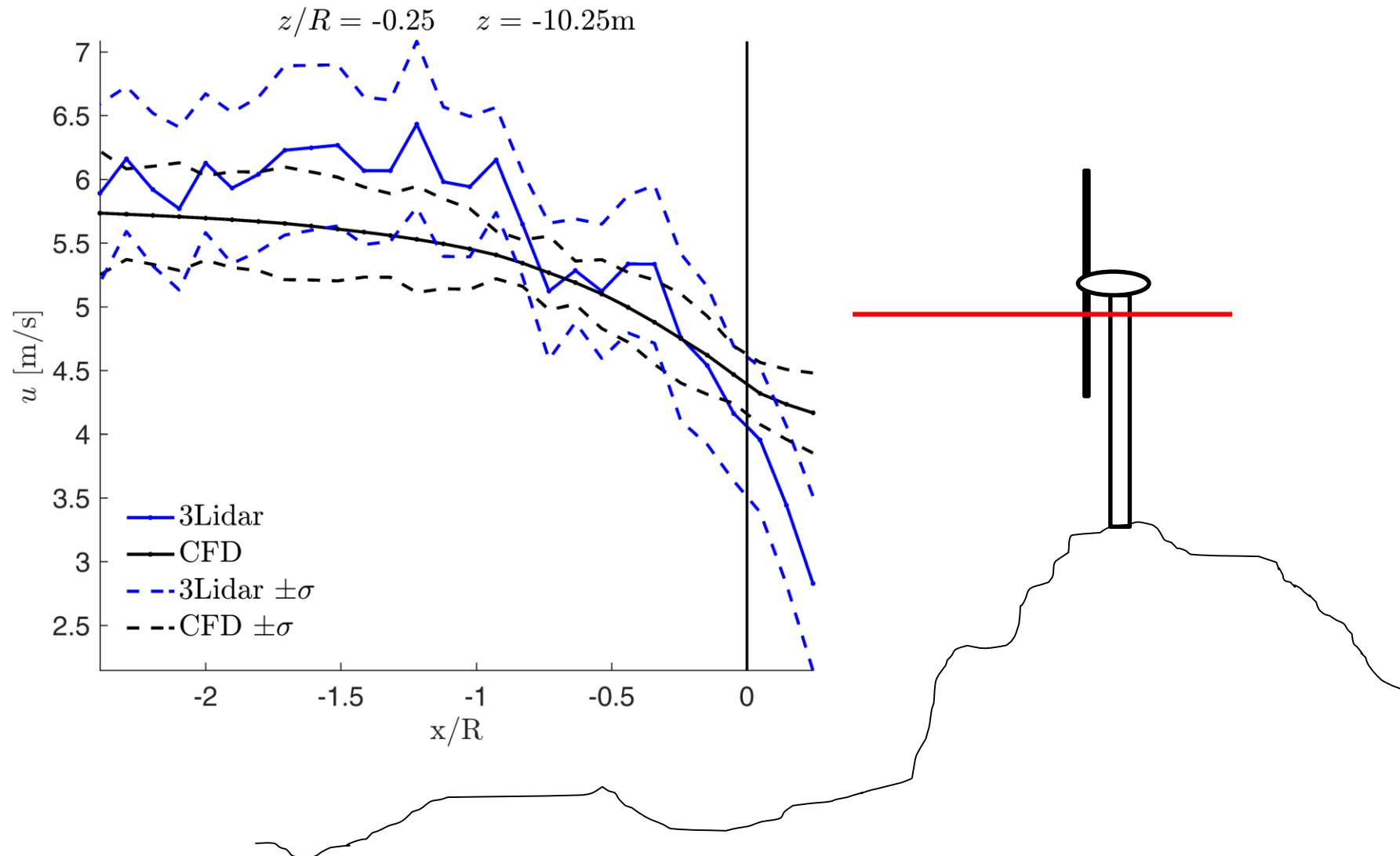
Comparaison triple-lidar and CFD



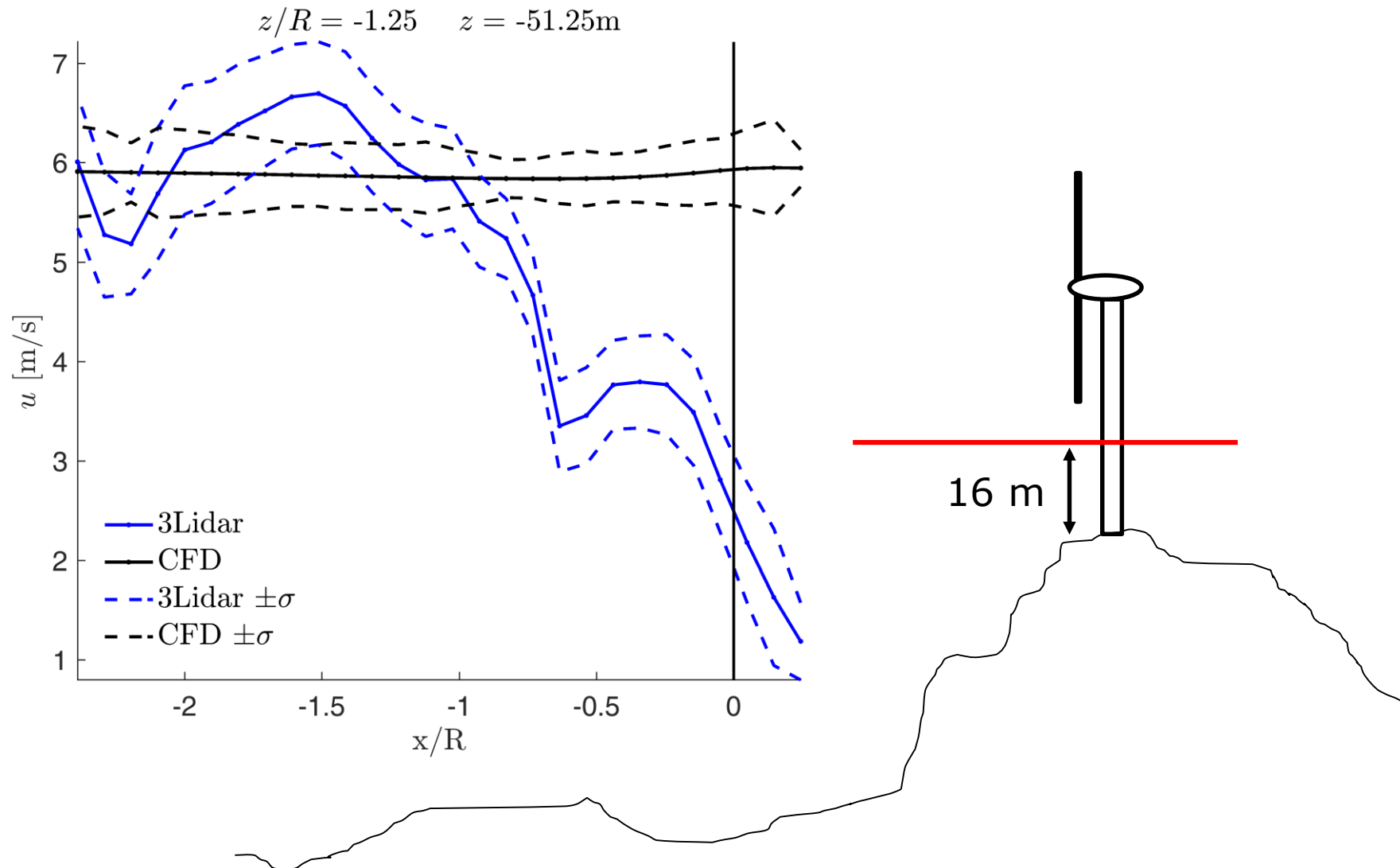
Comparaison triple-lidar and CFD



Comparison triple-lidar and CFD



Comparison triple-lidar and CFD




Conclusion

- Automated complex terrain simulations incorporating several pre-processing steps
- Triple-lidar shows high potential for complex flow measurements
- Large uncertainty in inflow conditions needs to be accounted for
- Steady-state RANS seems to capture induction zone correctly
- Computational uncertainty from:
 - Stratification
 - Roughness
 - Turbine
 - Terrain

Future work

- Investigate more measurement periods
- Include variability of wind direction into validation methodology
- Include stratification





Thanks for your attention!
Questions?

